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# Are Green Buildings Doing Enough?

## The role of green certification and gender on sick building syndrome

RANA ELNAKLAH [1,2] *, DANIEL FOSAS [1], SUKUMAR NATARAJAN [1]

[1] Department of Architecture and Civil Engineering, University of Bath, BA2 7AU, Bath, UK;
[2] Faculty of Architecture and design, Al-Ahliyya Amman University, Amman, Jordan;
* Corresponding author: rade20@bath.ac.uk

*ABSTRACT: One of the promised benefits of green buildings is providing healthier indoor environments for their occupants, however, this notion is still debated. To test this, a sample of 502 office-based workers from 13 air-conditioned office buildings (44.4% female and 55.6% male) in Jordan completed a questionnaire on Sick Building Syndrome (SBS) symptoms. The role played by gender in symptom-reporting was also investigated. Findings showed that building type made no significant difference to the prevalence of all SBS symptoms except the tiredness symptom which was slightly higher in the occupants of conventional buildings. Surprisingly, green buildings and conventional buildings had a higher occurrence of SBS symptoms than what industry standards allow for (up to 20%), suggesting that both building types would be classified as sick buildings. Results have also shown that the only significant difference between male and female workers was in the cough and sore throat symptom, which was reported more often by female workers. These findings reinforce the need for further attention to the occupants' perceived health in the green buildings, which may use as an indict of the building performance.*
*KEYWORDS: Green building, Sick Building Syndrome, Workplaces, Gender differences, Jordan*

### 1. INTRODUCTION

There is an increasing interest in how the Indoor Environment Quality (IEQ) of the green building promotes occupants' health, productivity, and satisfaction [1], particularly in office buildings, where employees spend about a third of their time at the workplace. This is could be an important issue considering that prolonged exposure to environments with poor IEQ parameters (e.g. air quality, lighting, thermal comfort, and acoustic) could lead to the well-known Sick Building Syndrome (SBS). According to a definition provided by the World Health Organization (WHO), the SBS is a group of medical symptoms that affect buildings' occupants and linked to the time spent in the building, and usually disappear when the person is away from the building [2].

The benefits of the green building design are not limited to reduction in the energy consumption and the subsequent harmful impact on the environment, they can also include potential benefits of creating a healthier indoor environment for occupants [3]. There is an increasing concern of whether green buildings deliver a healthier indoor environment they promised or rather, they increase the prevalence of SBS compared to conventional buildings [4].

To date, the research evidence on the effect of green buildings on the frequency of SBS symptoms is limited and equivocal. Although the study by Tham et al. in Singapore showed that the occupant perception of IEQ was slightly higher in the green building compared to the non-green building, no statistical differences in the proportion of SBS symptoms were found between the two occupants groups, also, the number of sick leave days was similar in both building types [5]. In contrast, a pre- and post-evaluation study in the United States showed an improvement in the employees' perceived health and reduction in the self-reported absenteeism after moving to the green buildings [6].

However, building physical features such as ventilation, lighting, temperature, etc. are not the only reasons behind the prevalence of SBS. Other psychological and physiological factors like job satisfaction, work-related stress, and gender differences might be as important in predicting SBS symptoms [7]. Of these, the effect of gender differences on the prevalence of SBS is still debated. Several attempts had been made to clarify the role gender differences might play in explaining changes to the frequency of SBS symptoms reported by occupants. Findings suggested that female workers usually reported higher levels of SBS symptoms (e.g. fatigue, headache, irritated eyes or nose, cough, and dry skin) compared to male workers [8–10]. This might be due to

three factors are namely biological (e.g. genes, hormones, and metabolism), behavioural (e.g. smoking, diet), and social (e.g. stress, social network) [7]. Unfortunately, other researchers did not consider gender as a predictor for the frequency of SBS symptoms, missing the opportunity to clarify whether this is indeed the case or not [11,12].

Given the uncertain evidence concerning the role of green certification and gender differences on SBS, this paper aims to answer two questions, which are studied from a holistic perspective that accounts for both factors the physical (i.e. building type) and physiological (i.e. gender differences) that underpin SBS prevalence, the two questions are:

- Do occupants in the green office buildings have a lower prevalence of SBS symptoms compared to their counterparts in the conventional buildings?
- Do gender differences affect the prevalence of SBS symptoms in the workplace?

## 2. METHODS

To answer the two questions, the data collection campaigns were designed to gather the responses of occupants in green and non-green office buildings, each of which has a random proportion of self-identified male and female employees. The dataset sample in this study reflects 502 responses from full-time office-based employees. The participants were selected randomly from five green buildings (n=261 respondents) and eight conventional buildings (n=241 respondents). Surveyed buildings are in Amman, the capital city of Jordan. All buildings are offices occupied by the private sector and did not report any known indoor air quality issues previously. The data were collected between summer 2017 – winter 2019.

### 2.1 Survey

The questionnaire was adapted from the Health and Work Performance Questionnaire produced by World Health Organization (WHO HPQ) [13]. It consists of two sections, the socio-demographic to collect information from employees on potential covariates (e.g. age, gender, work experience, job role, weight, and height). The second section includes ten questions to assess the prevalence of SBS, these questions were classified into three groups based on the WHO classification of SBS symptoms (Figure 1).

Respondents were asked to rate the frequency of SBS symptoms during the 28 days preceding the survey date. A 5-point Likert scale was used per question [14]. The scale ranged between 'not at all', 'a little of the time', 'some of the time', 'most of the time', 'all the time'. Further, the frequency of each symptom was compared to the ASHRAE standard 62.1 threshold [15]. According to this standard, a building can be labelled as sick when 20% or more of its occupants reported discomfort symptoms linked to the time spent in the building for a period exceeding two weeks.

The paper-based survey was used. The questionnaire was designed and wrote originally in English, then translated to Arabic, the first language of most participants. Both versions of the questionnaire were combined with the consent form and distributed in the selected buildings during working hours between 0900 – 1700. Of the 502 participants, 55.6 % were Male and 44.4 % were female.

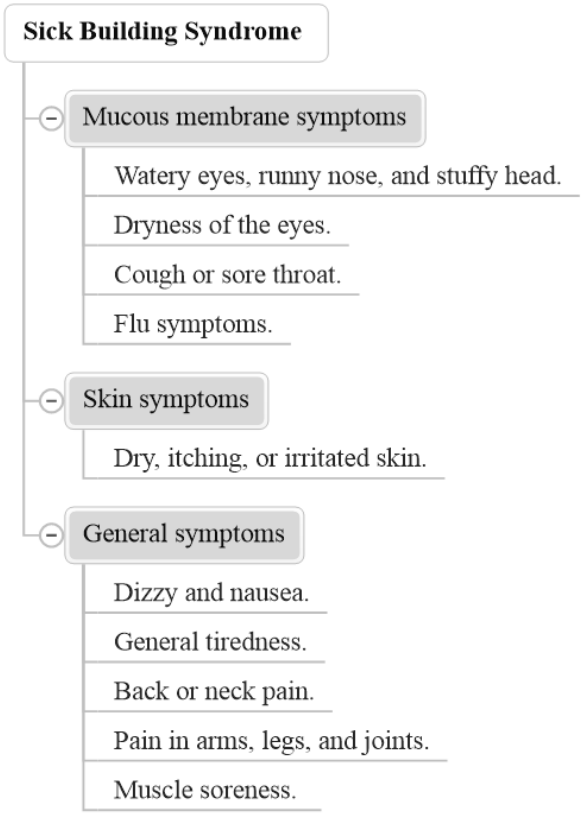


*Figure 1: The categories of sick building syndrome symptoms.*

### 2.2 Data Analysis

Each of the two research questions can be translated into the following questions: are the overall median prevalence of SBS symptoms the same between the two groups under consideration? Where the median is taken as an indicator of the overall change in self-reported SBS symptoms and the two groups under consideration refer to the conventional and green building types or male and female workers when addressing potential differences due to employees' self-

reported gender. Each question is studied through the following analysis methods:

I. Graphical inspection: A normalised stacked bar-chart of the response counts for each category and question, split by the variable of interest, should reveal any differences through the relative offset of the stacked bar of a group over that of the other.
II. Statistical hypothesis testing: We have conservatively chosen to appraise medians since responses to the questions in the survey are Likert items. To this end, the non-parametric Mann-Whitney U test (Wilcoxon's rank-sum test) is used to test the null hypothesis of no differences between groups at the 0.05 significance level.
III. Analysis of effect size: Coherently with the numerical analysis based on medians, the Rank Biserial Correlation (RBC) [16] was chosen as the measure of effect size, i.e. quantification of the magnitude of the difference between any two groups, regardless of their statistical significance. Similarly, to other correlation coefficients, the value of RBC is within [-1, +1], where 0 indicates no correlation, +1 a (perfect) positive correlation, and -1 a (perfect) negative correlation.

These were possible thanks to the following open source software: R [17], including the Tidyverse family [18] and HH libraries [19], and Python [20], including Numpy [21], Pandas [22] and Pingouin [23] libraries.

## 3. RESULTS and DISCUSSION

This section presents the results of the analysis of the impact of the green certification and gender differences on the SBS prevalence in workplaces, and it discusses the findings.

### 3.1 Building type and SBS

Figure 2 shows the breakdown of the scores for each SBS symptom in both building types. The occupants in the conventional buildings had a higher prevalence in most of SBS symptoms compared to the occupants in the green buildings. Moreover, from Figure 2 we can see that more than 20% of the participants in both building types experienced six SBS symptoms for '*some of the time*', these symptoms are namely watery eyes, neck pain, arms, legs and joints pain, muscle soreness, eye dryness and stuffy head, and tiredness (see Appendix A). Compare this finding to the ASHRAE standard 62.1 threshold, both building types in this study would be classified as sick.

Table 1 shows the results of the Mann-Whitney U test, which fails to reject the null hypothesis of no difference between the median scores according to the building type for nine SBS symptoms (In cases p-value > 0.05). While the U test suggests rejecting the null hypothesis of no difference between the median response according to the building type for tiredness symptom (U=27490.5, p-value < 0.01, RBC = 0.12), which was higher between the occupants in the conventional buildings.

This outcome is contrary to that of Tham et al. (2015) who reported no significant difference in the frequency of SBS symptoms between the occupants of the green and non-green buildings in Singapore, while both building types were below the recommended threshold [5]. This discrepancy could be attributed to the cultural and personal variances [24,25] or due to the differences in the buildings' characteristics [26].

*Table 1: Statistical analysis of individual SBS questions according to the Mann-Whitney U test (n Green=261, n Conventional=241); GB indicates green buildings and CB indicates conventional buildings.*

| SBS symptom | $\mu_{GB}$ | $\mu_{CB}$ | $\Delta\mu_{GB-CB}$ | U | Tail | p-value | RBC |
|---|---|---|---|---|---|---|---|
| Dizzy | 1 | 1 | 0 | 31475.0 | Greater | 0.49 | ≈0.00 |
| Tired | 1 | 2 | -1 | 27490.5 | Less | <0.01 | 0.12 |
| Back or neck pain | 1 | 2 | -1 | 31957.5 | Less | 0.62 | -0.02 |
| Pain in arms, legs, or joints | 1 | 2 | -1 | 30264.0 | Less | 0.22 | 0.03 |
| Muscle soreness | 1 | 1 | 0 | 30851.0 | Greater | 0.64 | 0.01 |
| Watery eyes, runny nose, or stuffy head | 1 | 1 | 0 | 31227.5 | Greater | 0.55 | ≈0.00 |
| Dryness of the eyes | 1 | 1 | 0 | 29869.5 | Greater | 0.84 | 0.05 |
| Cough or sore throat | 0 | 0 | 0 | 29605.5 | Greater | 0.89 | 0.05 |
| Flu symptoms | 0 | 0 | 0 | 31753.0 | Greater | 0.41 | -0.01 |
| Dry, itching or irritated skin | 0 | 0 | 0 | 29040.5 | Greater | 0.95 | 0.07 |

*Table 2: Statistical analysis of individual SBS questions according to the Mann-Whitney U test ($n_{Female}$=223, $n_{Male}$=279); F indicates female subjects and M indicates male subjects.*

| SBS Symptom | $\mu_M$ | $\mu_F$ | $\Delta\mu_{M-F}$ | U | Tail | p-value | RBC |
|---|---|---|---|---|---|---|---|
| Dizzy | 1 | 1 | 0 | 31238.5 | Greater | 0.47 | ≈0.00 |
| Tired | 1 | 1 | 0 | 28498.0 | Greater | 0.96 | 0.08 |
| Back or neck pain | 1 | 2 | -1 | 30740.5 | Less | 0.41 | 0.01 |
| Pain in arms, legs, or joints | 1 | 2 | -1 | 28826.0 | Less | 0.07 | 0.07 |
| Muscle soreness | 1 | 1 | 0 | 29961.0 | Greater | 0.77 | 0.04 |
| Watery eyes, runny nose, or stuffy head | 1 | 1 | 0 | 30631.0 | Greater | 0.62 | 0.02 |
| Dryness of the eyes | 1 | 1 | 0 | 27601.5 | Greater | 0.99 | 0.11 |
| Cough or sore throat | 0 | 1 | -1 | 26960.5 | Less | <0.01 | 0.13 |
| Flu symptoms | 0 | 0 | 0 | 27612.5 | Greater | 0.99 | 0.11 |
| Dry, itching or irritated skin | 0 | 0 | 0 | 28835.0 | Greater | 0.94 | 0.07 |

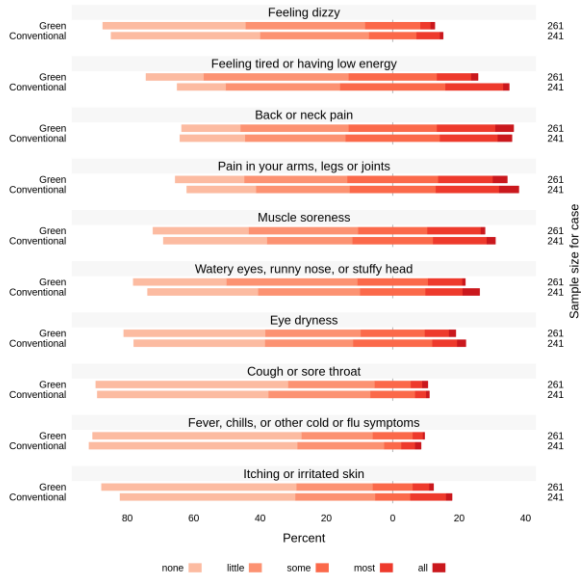


*Figure 2: Breakdown of responses to SBS symptoms questions according to the building type (statistical analysis in Table 1).*

### 3.2 Gender differences and SBS

Figure 3 shows the results of the breakdown for the scores of SBS symptoms according to the occupants' gender. The female workers tend to have a higher frequency of SBS symptoms compared to the male workers for all symptoms except two symptoms are namely dizzy and watery eyes, runny nose and stuffy head, that were reported more often between male workers.

Table 2 shows the results of the Mann-Whitney U test which fails to reject the null hypothesis of no difference between the median responses according to the occupants' gender for all SBS symptoms (In cases p-value > 0.05) except the cough and sore throat symptom (U=26960.5, p-value < 0.01, RBC = 0.13), which has a negligible effect size.

This finding is consistent with other studies in this area that found the gender differences is small and inconsistent in the self-reported symptoms [12]. Also, the differences between male and female workers in SBS were observed to be reported frequently in particular symptoms included cough, sore throat, fatigue, and eye irritation [9], this variance can be attributed to the biological and behavioural differences.

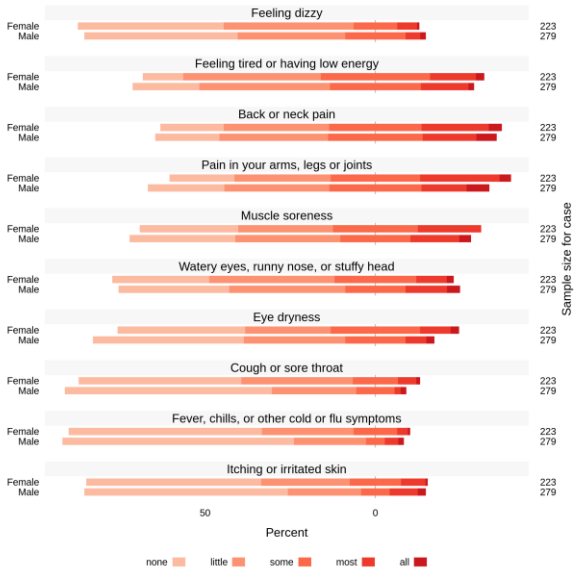


*Figure 3: Breakdown of responses to SBS symptoms questions according to gender differences (statistical analysis in Table 2).*

## 4. CONCLUSION

This study investigated if the occupants of green office buildings in Jordan have a lower prevalence of SBS symptoms compared to those in the conventional buildings. It investigated as well if gender differences play a role in the frequency of SBS symptoms.

The findings of our analysis based on 502 office occupants show that building type made no significant difference to the frequency of all SBS symptoms except the tiredness symptom, which was found to occur more

often between the occupants of conventional buildings. However, according to the ASHRAE standard 62.1 threshold, both building types can be classified as sick buildings, as more than 20% of their occupants had experienced six SBS symptoms *'some of the time'* during 28 days preceding the survey.

Also, the present analysis indicates that female and male office workers reported the same frequencies for most of SBS symptoms, with a statistically significant higher prevalence of cough and sore throat symptom between the female workers albeit of negligible effect size. However, this study had a cross-sectional research design, and an absolute conclusion of causation cannot be made, thus longitudinal with repeated measures could assist in capturing any differences between the two samples.

Overall, our findings highlight a clear problem in the office buildings in Jordan and suggest that architects, designers, and building owners need to pay further attention in the future to the unintended consequences of green office buildings, that could potentially impose on employee health and affect the work performance and the financial return of the business.

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**DISCLOSURE STATEMENT**

The authors reported no potential conflict of interest.

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**APPENDIX A:** The percentage of occupant response for each SBS symptom in both buildings types during 28-day preceding the survey

| | None of the time | | Little of the time | | Some of the time | | Most of the time | | All of the time | |
|---|---|---|---|---|---|---|---|---|---|---|
| SBS Symptom | GB | CB | GB | CB | GB | CB | GB | CB | GB | CB |
| Dizzy | 43% | 45% | 36% | 33% | 17% | 15% | 3% | 7% | 15% | 1% |
| Tired | 17% | 15% | 44% | 34% | 27% | 32% | 10% | 17% | 2% | 2% |
| Back or neck pain | 18% | 20% | 33% | 30% | 27% | 29% | 18% | 17% | 5% | 4% |
| Pain in arms, legs, or joints | 21% | 21% | 31% | 28% | 28% | 26% | 16% | 19% | 4% | 6% |
| Muscle soreness | 29% | 31% | 33% | 26% | 21% | 24% | 16% | 16% | 1% | 2% |
| Watery eyes, runny nose, or stuffy head | 28% | 33% | 39% | 31% | 21% | 20% | 10% | 11% | 1% | 5% |
| Dryness of the eyes | 43% | 39% | 29% | 27% | 20% | 24% | 7% | 7% | 2% | 2% |
| Cough or sore throat | 58% | 51% | 26% | 31% | 11% | 14% | 3% | 3% | 2% | 1% |
| Flu symptoms | 63% | 63% | 21% | 26% | 12% | 5% | 3% | 4% | 0 | 2% |
| Dry, itching or irritated skin | 59% | 53% | 23% | 24% | 12% | 11% | 5% | 11% | 1% | 2% |